Analog Electronics Exercises

Session 4

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Exercise 1

1) Resistors R_1 and R_2 connected in series are at equilibrium temperature T. P_{12} is the noise power transferred from resistor 1 to 2 and vice versa is P_{21}. Calculate P_{12} and P_{21} for an arbitrary bandwidth B. What is the relationship between P_{21} and P_{12}?

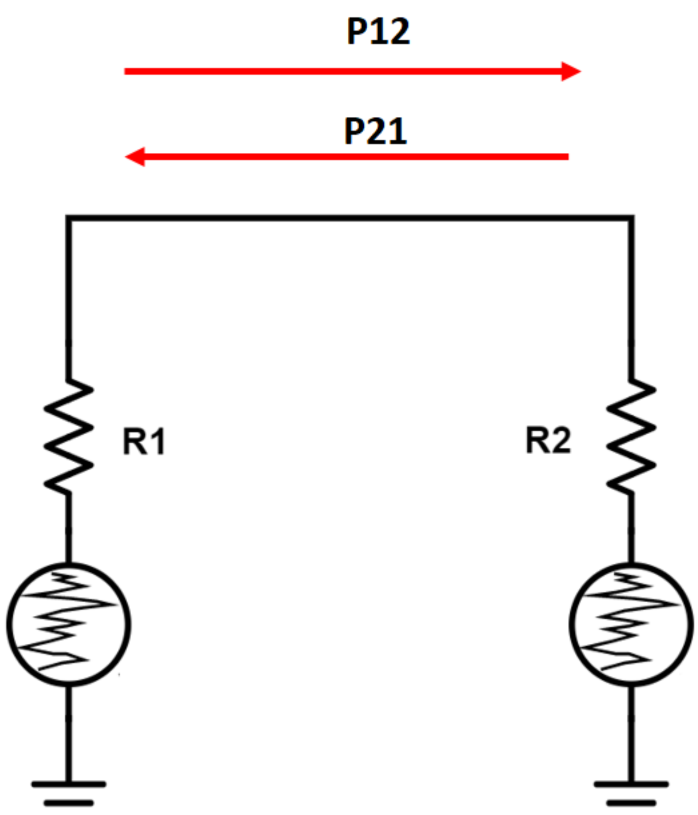

Figure 1: Resistor R_1 and R_2 connected in series

Exercise 2

1) In Figure A, calculate integrated noise across the capacitor? Also calculate the same when resistor R is increased to $2R$ as in Figure B?

2) Plot the noise power spectral density in both cases across the capacitors with frequency? Take $R = 1K$ and $C = 1pF$, $T = 300K$, $k = 1.38 * 10^{-23}$. In the second case change the value of the resistance to 2K.

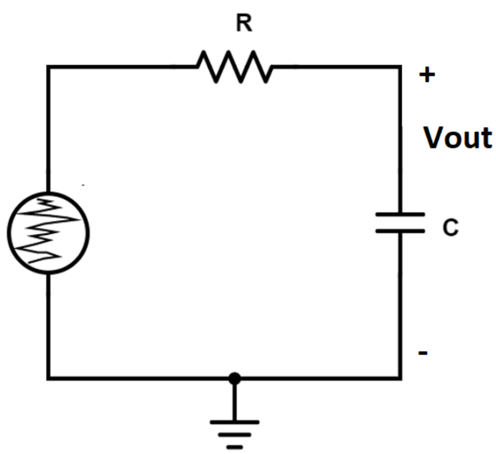

Figure A

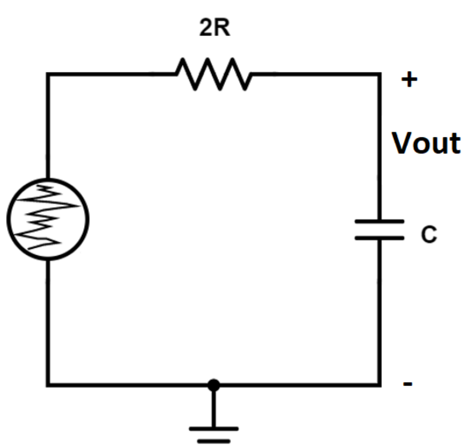

Figure B

Figure 2: RC circuit

Exercise 3

1) Calculate output and input referred noise of common source amplifier? Assume transistor with infinite output impedance and trans-conductance gm. Consider only thermal noise for calculations.

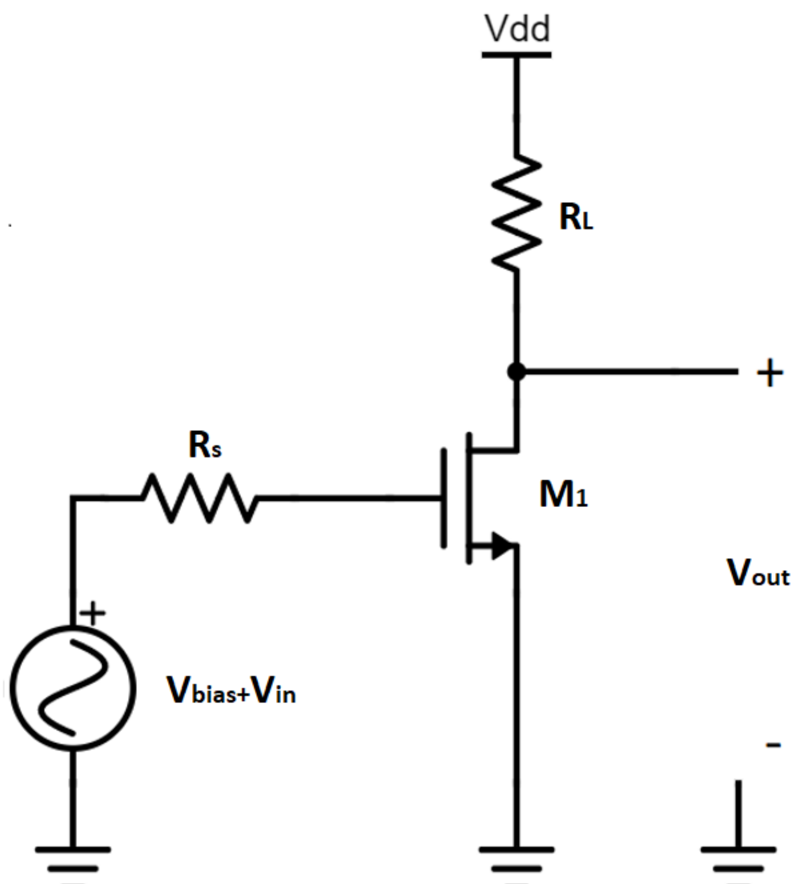

Figure 3: Common source Amplifier

Exercise 4

1) Calculate output and input referred noise of the degenerated amplifier in the figure? Assume transistor with infinite output impedance and trans-conductance gm. Is the input referred noise higher or lower compared common source amplifier having similar gm? Consider only thermal noise for calculations.

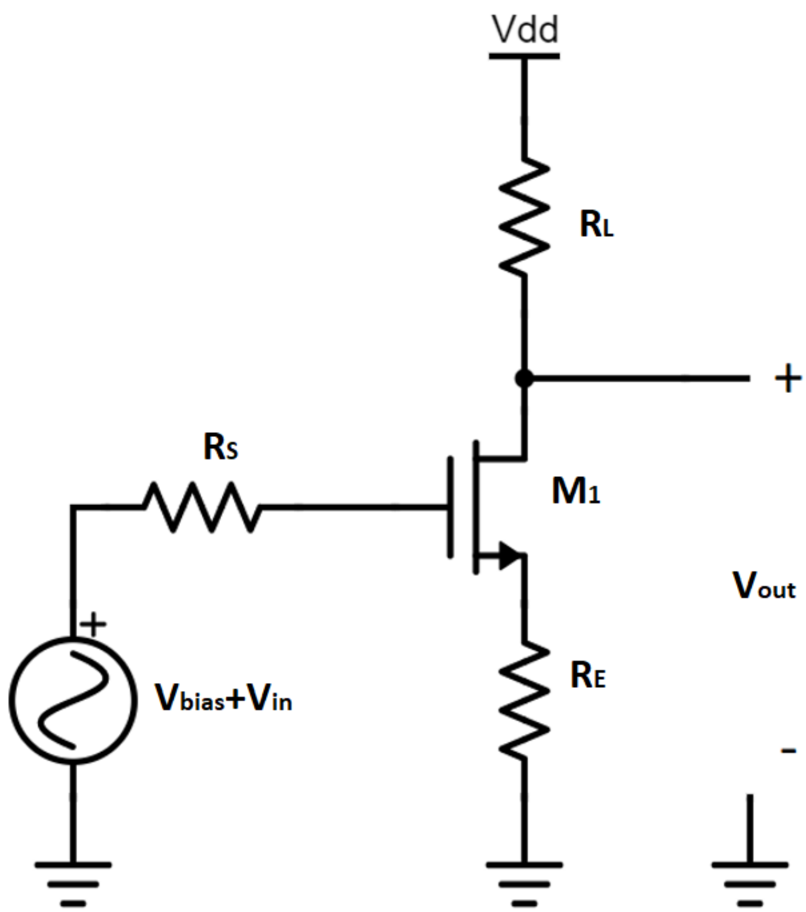

Figure 4: Amplifier with Degeneration resistance RE

Exercise 5

1) Calculate output and input referred noise of the common drain amplifier in the figure? Assume transistor with infinite output impedance and transconductance gm. Consider only thermal noise for calculations.

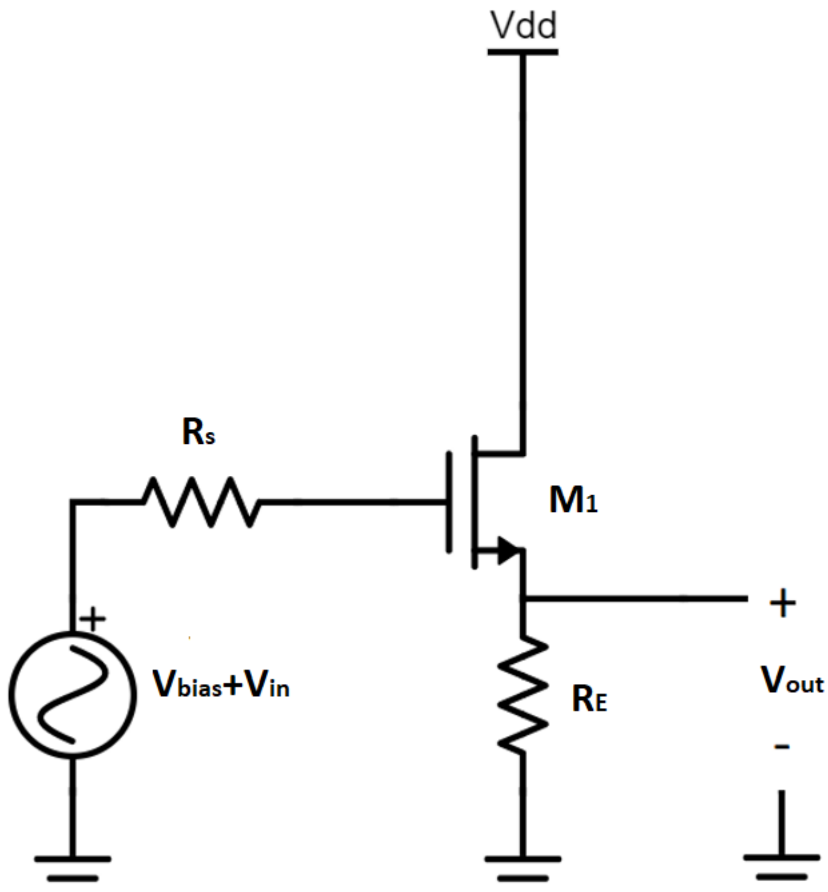

Figure 5: Common drain amplifier

Exercise 6

1) Calculate the input referred noise of the cascaded common source amplifier as shown in the figure. The transistors M_1 and M_2 have trans-conductance gm_1 and gm_2. Assume only thermal noise and neglect the flicker noise of transistors. Also assume infinite output impedance with all transistors in saturation.

2) What are the noise sources contributing most of the noise . From the expression you will see that in order to decrease the noise contribution of the second stage you can increase the gain of the first stage ? Is their any limit (Hint:Take into account channel length modulation and hence finite output impedance of the transistor)? Any technique you can try to overcome the limit ?

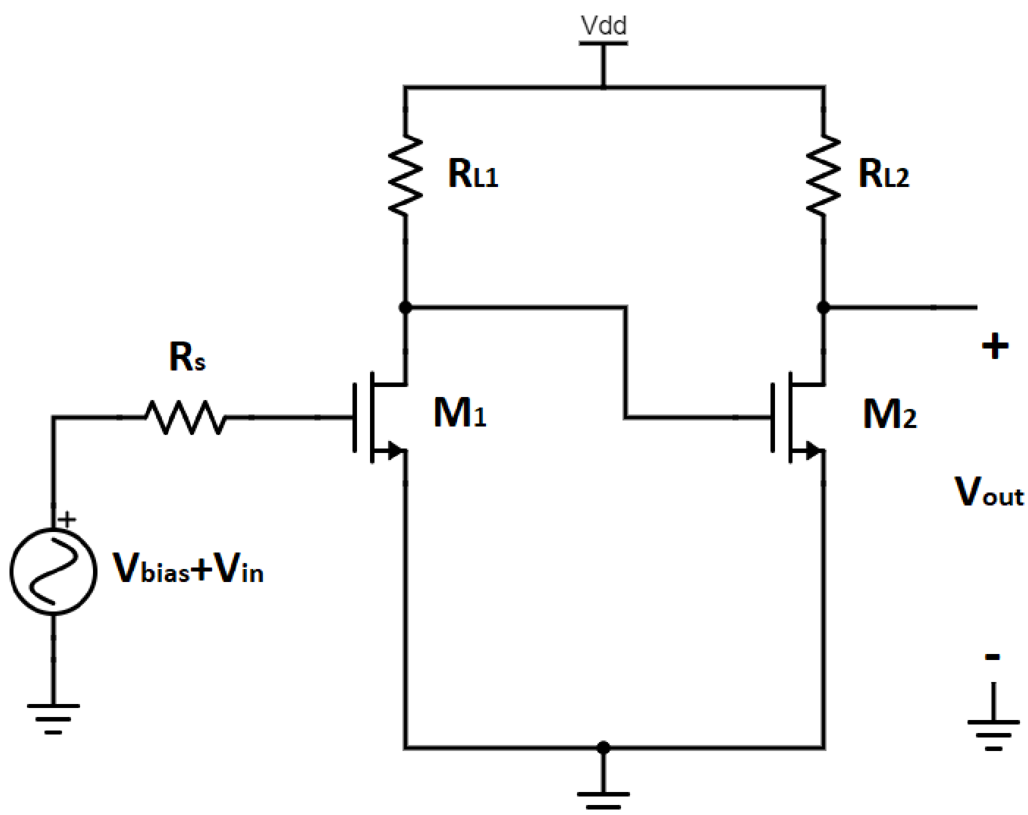

Figure 6: Cascaded common source amplifier

3) Now add capacitance C_{L1} to the output of the first stage. How will it change the input referred noise contribution of the second stage with frequency?

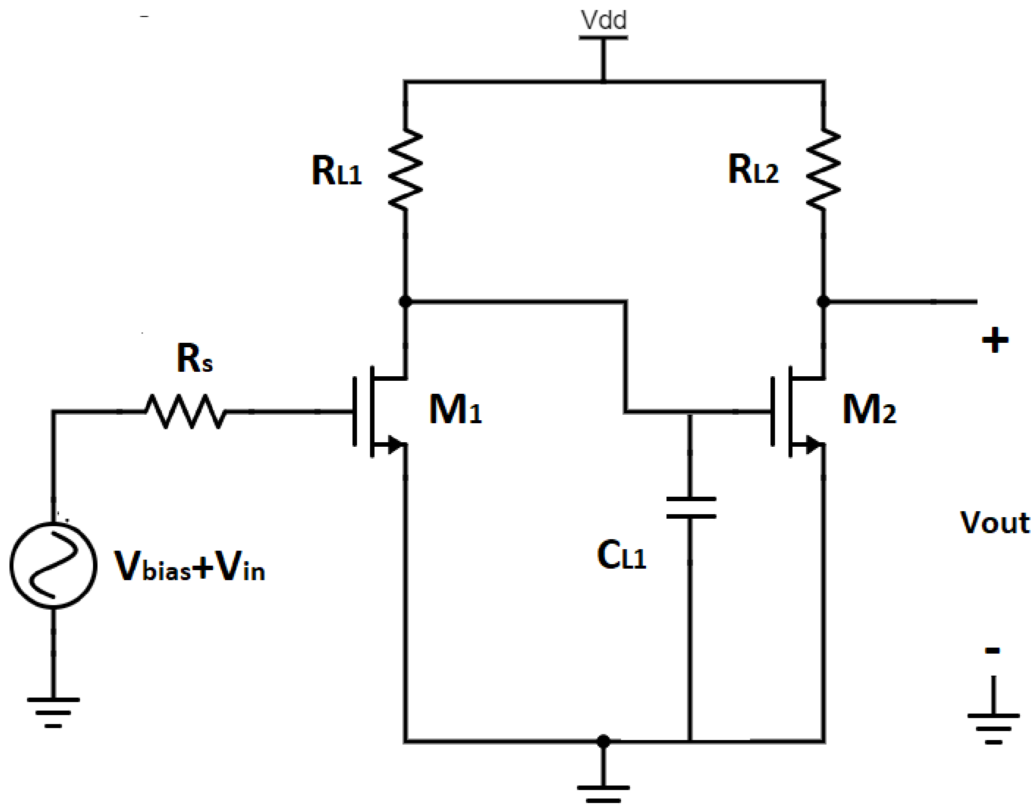

Figure 7: Cascaded amplifier with capacitive load in first stage

Exercise 7

Figure shows common source amplifier with gate to source capacitance C_{gs}. In the figure, $R_L = 5K$, $R_S = 100K$, $C_{gs} = 33f$ and $gm = 1mS$. For transistor M1 drain flicker noise current spectral density at 1Hz=$5 * 10^{-15} A^2/Hz$.

1.)Plot the output and input noise voltage spectral density with frequency in matlab. In this question take into account both thermal and flicker noise contribution. Take $\gamma = \frac{2}{3}$

2.)The input signal bandwidth is from 10MHz to 100MHz. Calculate the input referred integrated noise in the given bandwidth and also minimum detectable signal value.

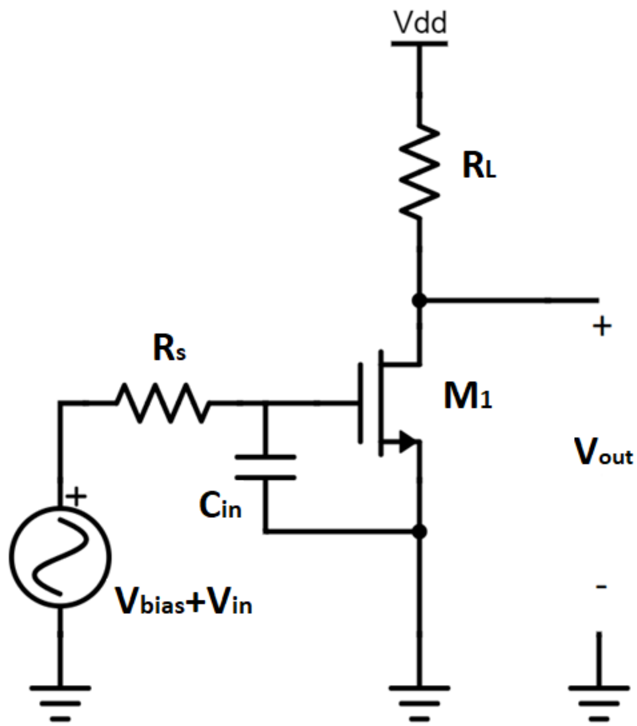

Figure 8: Common source Amplifier

Exercise 8

1) Figure shows a different pair. Transistor M_1 and M_2 have trans-conductance gm. Assuming bias current from transistor M_3 does not add any noise. What is total input referred noise of the differential pair. Take into account only thermal noise.

2) Now imagine transistor M_3 adds noise. Do you think it will add noise to the differential output? Can flicker noise in M_3 change the gain of the amplifier with time? Assume that the input is very small signal.

3) What do you think will be the impact of noise in supply Vdd

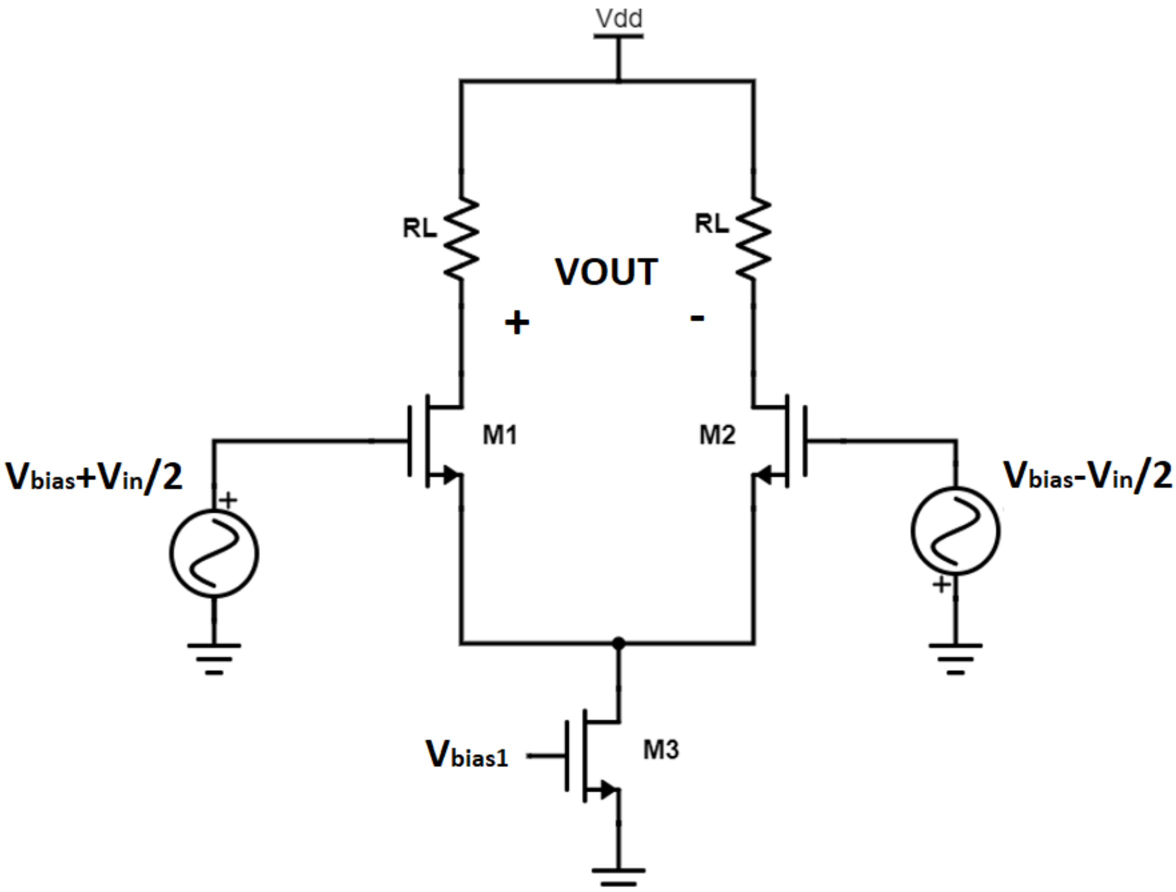

Figure 9: Differential Amplifier

Exercise 9

1.)The figure A shows trans impedance amplifier. Trans-impedance amplifier converts input current to voltage. It can be built by using ideal op-amp and feedback resistor as connected in Figure A. Assuming input referred noise of the opamp used is V_{namp}^2. Derive an expression of input referred noise.

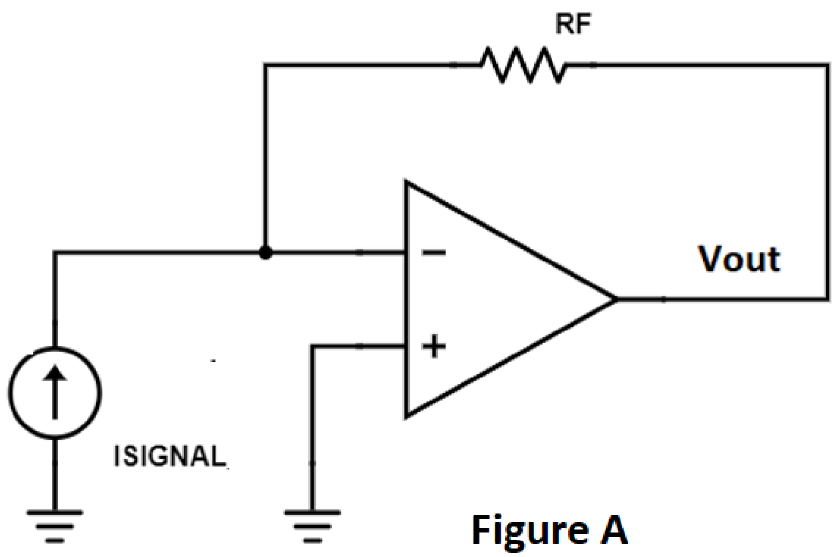

Figure 10: Trans-impedance Amplifier

Exercise 10

Assume each of the transistors are in saturation and take into account the effect of output impedance and thermal noise of the transistors.

1) Calculate the input referred noise contribution at lower frequency from the transistors M_{1A} , M_{1B} , M_{2A} and M_{2B}. Assume the trans-conductance of M_{1A} and M_{1B} is gm_n and trans-conductance of M_{2A} and M_{2B} is gm_p

2) Can you comment on noise contribution of transistors M_3 and M_4 at very low frequencies. At what frequency approximately will the 2^{nd} stage noise will begin to dominate(Hint: Frequency at which first stage gain drops to 1). Take low frequency output impedance of first stage as R_{o1} and R_{o2}

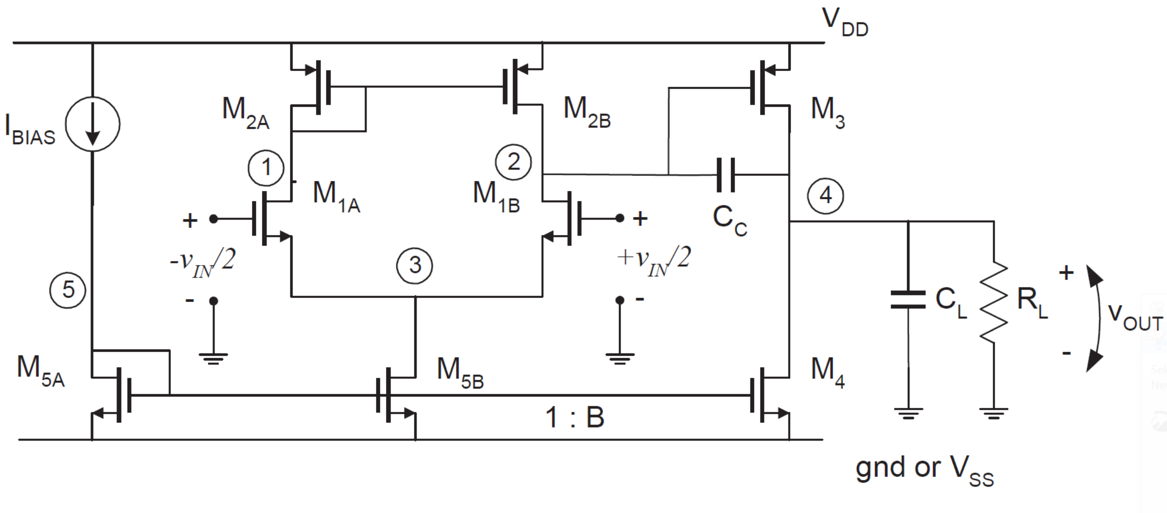

Figure 11: 2 Stage OTA